COPING WITH FLOODS – THE EXPERIENCE OF MOZAMBIQUE[1]

Álvaro CARMO VAZ

Professor, Faculty of Engineering, Eduardo Mondlane University
Director, CONSULTEC – Consultores Associados Lda.
e-mail: carmovaz@tropical.co.mz

ABSTRACT

A summary review is made of the major floods that have occurred in Mozambique since the Independence in 1975, describing the most important negative impacts and consequences.

Various types of measures for flood mitigation are analysed, considering how they have been used in past floods and their potential for coping with floods in the future. These measures are grouped into structural (dams, levees, flooding areas, river training) and non-structural measures (flood zoning, flood management, flood warning systems, emergency plans, raising awareness, insurance).

The paper briefly refers the need for adequate and comprehensive reports on past floods and some related research areas.

1 THE FLOOD PRONE RIVERS OF MOZAMBIQUE

More than 50% of the Mozambican territory is part of international river basins – from South to North, the Maputo, Umbeluzi, Incomati, Limpopo, Save, Buzi, Pungoé, Zambezi and Rovuma, see figures 1 and 2.

All these rivers have their flood plains inside Mozambique, with the exception of the Rovuma river that forms the border between this country and Tanzania. The largest basins are the Zambezi (1,200,000 Km^2) and the Limpopo (412,000 Km^2) and the smallest one is the Umbeluzi (5,600 Km^2) with the others ranging from about 30,000 to 150,000 Km^2.

The climatic conditions of Mozambique indicate that the country is subject to various types of events that can originate floods: cyclones and tropical depressions from the Indian Ocean and cold fronts from the south.

Therefore, considering the extension of the country, the large areas of its major river basins and the climatic conditions, it is quite natural that floods of various degrees of severity occur repeatedly, sometimes with devastating effects as it happened with the floods of February – March 2000.

2 BRIEF SUMMARY OF PAST MAJOR FLOODS

2.1 MAJOR FLOODS SINCE THE INDEPENDENCE (1975)

Mozambique has a long history of floods. Major floods have been recorded in all the international river basins shared by Mozambique, with the exception of the Rovuma. For the national river basins, only the Licungo has experienced floods of some importance.

[1] Adapted from a presentation by the author to the International Conference for Mozambique Floods, Maputo, 27-28 October 2000.

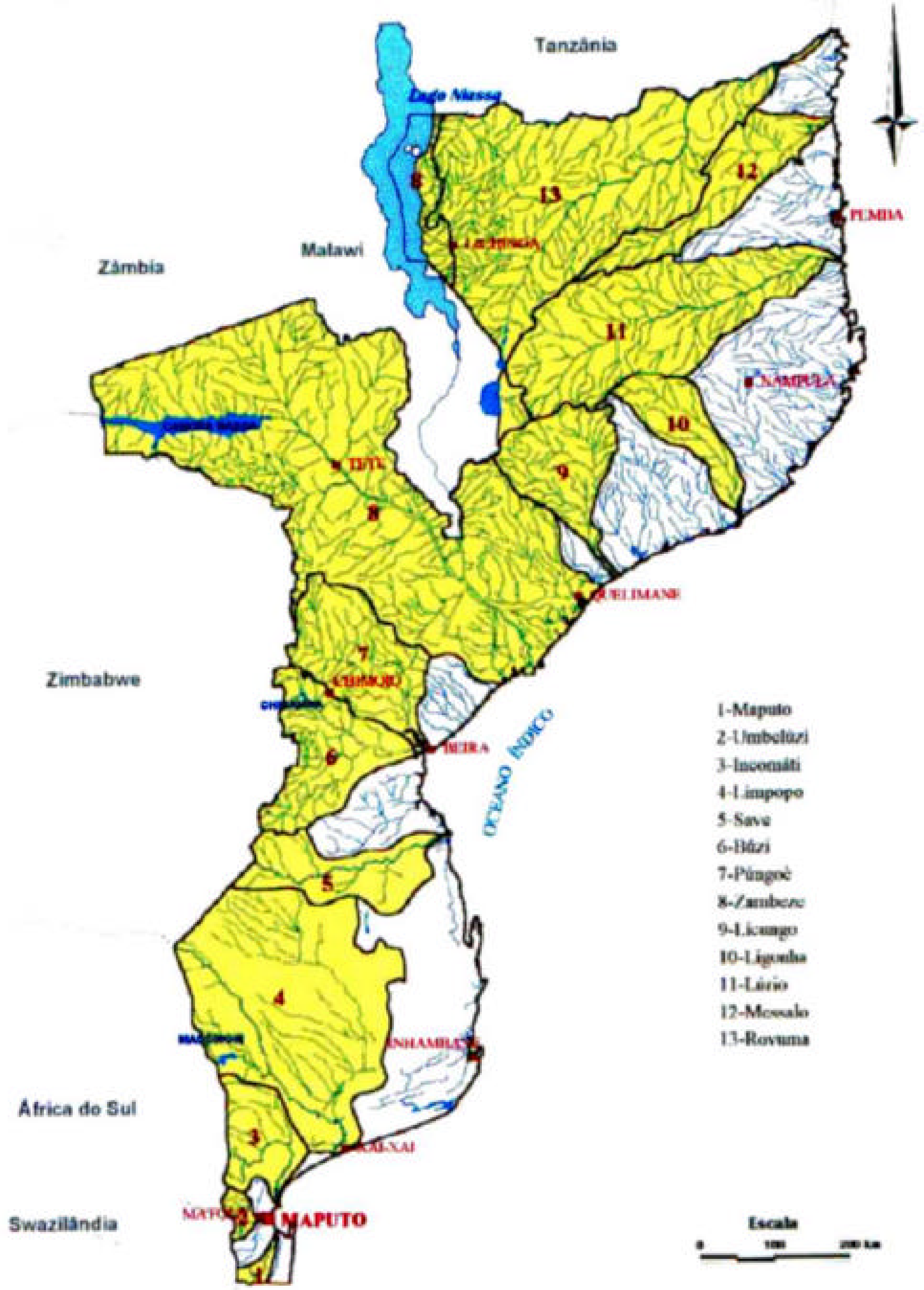

Figure 1 – Main river basins of Mozambique

There has been also damages and disruption of communications caused by floods of small rivers along the coast, particularly road cuts and serious erosion in the coastal dunes.

Floods were experienced in the years 1976, 1977, 1978, 1981, 1984, 1985, 1996, 1997, 1999 and 2000, in the various river basins.

2.2 FLOODS IN THE MAPUTO RIVER

Mozambique, South Africa and Swaziland share the Maputo river basin. The only major flood in the Maputo river in the last 25 years was in February 1984 when cyclone "Domoina" hit the southern part of Mozambique and also South Africa and Swaziland. The cyclone also caused floods in the Umbeluzi and the Incomati river basins.

This flood provoked the first spillway discharges of the large Pongolapoort dam in South Africa. No flood warning system was in place and so no effective warning could be given to the rural population. Many people living and doing agriculture along the riverbanks died during the flood. However, this was not well established for various reasons:

- the flood in the Maputo river was overshadowed by the simultaneous floods in the Umbeluzi and Incomati rivers that affected more populated and economically important areas
- difficulty in access to the area, that would become almost impossible a few months later due to the increase of the Renamo guerrilla warfare immediately after the Inkomati Agreement between Mozambique and South Africa

There were also some economic damages but this was not very important except for tourism at the southern beaches (that anyway would become blocked by the civil war).

2.3 FLOODS IN THE UMBELUZI RIVER

Mozambique and Swaziland share the Umbeluzi river basin. Mozambique built in 1988 a large dam on the Umbeluzi river, the Pequenos Libombos dam. The Umbeluzi river basin suffered a devastating flood in 1984, caused by the cyclone "Domoina". Other floods followed in the years 1999 and 2000.

The flood originated from cyclone "Domoina" is the biggest flood recorded until now in the Umbeluzi basin. It was caused by intense rainfall in Swaziland and Mozambique in the end of January, over the Umbeluzi own basin and also on the main tributary, Movene. As a result:

- many people died (the numbers were never well established but some estimates point out to more than 100 deaths in the Umbeluzi, Incomati and Maputo basins)
- large areas at the Lower Umbeluzi became flooded
- the construction works of the Pequenos Libombos dam were seriously affected
- the water intake and treatment plant of the Maputo city water supply were inundated and the urban water supply was out of service for days
- the electricity supply was also disrupted for days
- the road connecting Maputo to Swaziland and South Africa was flooded
- the railway bridge near Boane had some piers badly damaged

In 1999, the flood in the Umbeluzi basin was caused mainly by the tributary Movene as the Pequenos Libombos reservoir absorbed almost completely the peak flood along the main river. The Movene flood endangered some bridges on the road to South Africa and created some minor flooding but flood warnings were issued and there was no loss of lives or significant economic damages.

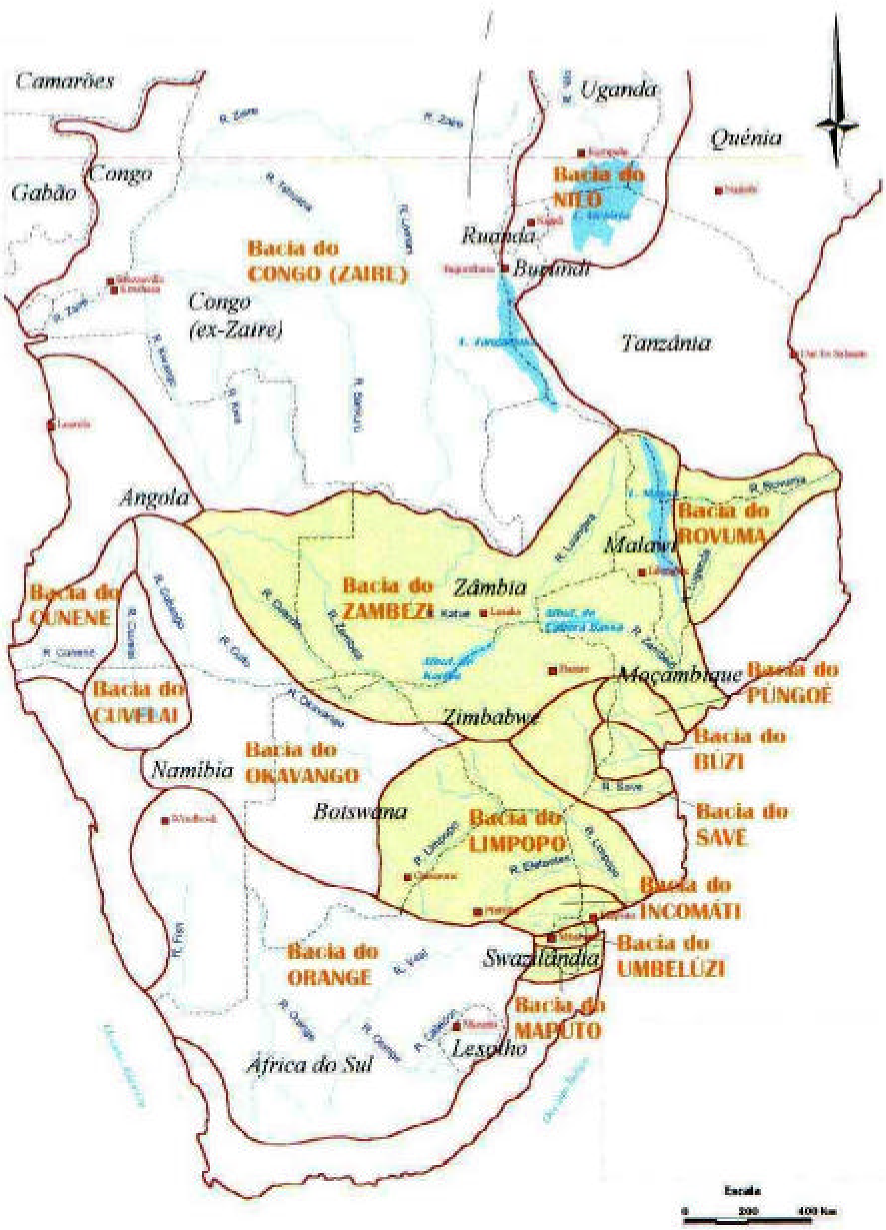

Figure 2 – International river basins shared by Mozambique

The floods in 2000 in the Umbeluzi basin were quite serious, although nothing in comparison to what occurred in the same year in the Limpopo basin. They were also of a lesser magnitude than the one in 1984. Besides, the existence and operation of the Pequenos Libombos reservoir and of a flood warning system made also a significant difference in relation to 1984, contributing to reduce the loss of lives and the economic damages. In spite of this, there were some important damages, particularly due to the Movene river:

- 4 people died
- the road between Maputo and Boane was flooded, cutting for days the communications between Maputo and South Africa and Swaziland
- the road between Boane and Moamba was flooded, cut and damaged by the Movene river. However, the road connection to South Africa could be re-established even before the repair of that road by temporary using the new Maputo Corridor road (although still in construction).

2.4 FLOODS IN THE INCOMATI RIVER

Like the Maputo, the Incomati river basin is also shared by Mozambique, South Africa and Swaziland. Mozambique completed in 1989 the construction of a large dam (Corumana) on the Sabié river, the main tributary to the Incomati inside Mozambique.

In 1976, there was a flood in the Incomati river basin, affecting the Lower Incomati. There was no loss of lives but important economic damages were suffered by the banana plantations, that were completely destroyed, and by the sugar cane plantation of MARAGRA. The EN1 road was cut and the Incoluane weir was damaged. This was the biggest recorded flood in the Incomati river until the flood in 2000 (there is, however, flood marks indicating that a bigger flood occurred in 1937, before systematic recording of water levels and discharges were initiated).

All the physical damages were repaired, including the dykes that protected MARAGRA's sugar cane plantation. It is interesting to note that, although the dykes were breached in a river section where the width between the dykes on both sides of the river is very small, they were rebuilt in the same place.

The cyclone 'Domoina" also caused a flood in the Incomati river in 1984, with inundation of agricultural areas in the Lower Incomati and some disruption of the water supply of Moamba town and of the EN1 road. The most serious consequence of this flood was the destruction of the Moamba bridge that jeopardised for many months the communication with the Sabié district and affected the construction works of the Corumana dam.

Smaller floods occurred in 1985 and 1996, again with some inundation of agricultural areas and minor damages to the road infrastructure.

The floods in February 2000 are the biggest ever recorded. They resulted from a combination of a very wet season started in December 1999, followed by a tropical depression that remained stationary over the upstream part of the basin in South Africa, producing extremely high flows in the Crocodile and Sabié rivers in that country and crossing the borders into Mozambique. The Kruger Park in South Africa, which is crossed by the Crocodile and Sabié rivers, experienced the biggest flood since its creation in 1898.

Some attenuation of the Sabié flood was achieved at the Corumana dam. DNA (National Directorate of Waters) and ARA Sul (Regional Water Administration – South) issued flood warnings, although it became clear that the flood propagation model that was used was inadequate and unable to make reasonable forecasts of water levels at the Lower Incomati region. However, there was almost no loss of lives.

The main impacts of the floods were:

- the EN1 road was cut near Incoluane, blocking the connection between Maputo and the North of the country
- the new bridge at Moamba, built after the 'Domoina" flood was completely destroyed, cutting the road connection to the Sabié district
- the railway lines to South Africa and to Zimbabwe were seriously affected

- the irrigation areas of Xinavane, Sabié and MARAGRA were flooded. MARAGRA lost its entire plantation of sugar cane and the irrigation scheme of Sabié suffered important damages
- agricultural areas in the Lower Incomati were inundated

2.5 FLOODS IN THE LIMPOPO RIVER

Four countries share the Limpopo river basin: Mozambique, Botswana, South Africa and Zimbabwe. Mozambique finished in 1977 the construction (1st phase) of a large dam, Massingir, on the Elephants river, the most important tributary of the Limpopo river.

Since Mozambique became independent in 1975, the Limpopo river basin has been the region most devastated by floods. This is caused by the natural characteristics of the basin itself and the climate in the region, on one hand; on the other hand, the Limpopo is the Mozambican basin with more development encroached in the flood plain.

Floods in the Limpopo basin in the last 25 years occurred in 1975, 1977, 1981, 1996 and 2000. The floods in 1975, 1981 and 1996 were of smaller magnitude and caused inundation at a limited scale, besides some concern about the roads, bridges and protection dykes.

In 1981, DNA had a flood warning system based on a simple flood propagation model that allowed for a reasonable forecast to be made and issued on time. Massingir dam, located on the Elephants river, the main tributary of the Limpopo river, was also operated to avoid the simultaneity of the peaks of the Limpopo river and of the discharges of the dam.

In 1996, the major concern was with the Massingir dam, which has serious leakage problems (putting its stability at risk) and is due to start a rehabilitation program. The incoming flood to the reservoir was big and for the first time since its construction in 1977 floodwater was passing through its non-gated spillway.

The flood that occurred in February 1977 was the worst that occurred in Mozambique until that date. The whole Lower Limpopo was flooded. The Massingir dam, that was under construction, provided for an important attenuation, storing a large volume of floodwater. The main impacts and consequences of this flood were:

- many people died
- damages of some protection dykes
- inundation of some areas in the (protected) irrigation perimeters of Chokwé and Lower Limpopo
- enormous damages to many small rural villages in the flood plain
- destruction of bridges in the EN1 road to Xai Xai

Immediately after the flood, the Government launched a program of re-settlement of people of the rural villages, creating new villages in more secure areas and with better infrastructures and social services (“aldeias comunais”). The damages were repaired and the bridges were re-built.

The recent floods of February 2000 largely surpassed the flood of 1977 in its magnitude and impacts. It was caused by a stationary tropical depression over Mozambique, South Africa, Botswana and Zimbabwe, during the first two weeks of February, originating a first flood wave. While the Limpopo river was still in flood, the cyclone “Eline” crossed Mozambique and caused heavy rainfall in South Africa, Zimbabwe and Botswana, originating the second and more damaging flood wave. The situation in the Lower Limpopo became even worse when the Massingir reservoir received also a big flood of the Elephants river, forcing the dam to raise enormously its discharge that added up to the Limpopo river own floodwaters[2].

The major impacts and consequences of this flood were:

- more than 500 hundred people died (the estimate of the total number of deaths for all the flooded basins is around 700) and more than 200,000 forced into refugee camps
- the inundation by more than 2 m of water of the city of Chokwé, forcing its evacuation. The city suffered large damages, the water supply and electricity systems were broken and it was more than a month later that its inhabitants could return and the social and economic activities could re-start
- the inundation by about 3 m of the downtown part of the city of Xai Xai, capital of the Gaza Province. The damages were extremely severe, both for infrastructures like streets, urban and sewerage water supply, electricity and protection dykes as for private and public buildings.
- serious damages to the Macarretane dam that serves the Chokwé irrigation scheme, affecting also the road and railway line to Zimbabwe
- serious damages to the Chokwé irrigation scheme – protection dykes, main and secondary irrigation canals, field infrastructure
- serious damages to the roads and bridges in the approach to Xai Xai, preventing for more than 6 months normal traffic along the EN1 road
- serious damages to the railway line to Zimbabwe
- complete disruption of the social and economic life in vast areas of the Gaza Province and, indirectly, also in Inhambane Province.

The flood in the Limpopo river was so extreme and the inundation was so high that for some time, a water connection was established between the Limpopo and the Incomati rivers through the tributary of the Incomati, Mazim'chopes.

2.6 FLOODS IN THE SAVE AND THE BUZI RIVERS

Both the Save and the Buzi basin are shared between Mozambique and Zimbabwe. A large dam, Chicamba, has been built before the Independence for hydropower, on the Revué river, the major tributary of the Buzi river.

Since the Independence, only this year there was a major flood in these two river basins. The Save and Buzi basins in Mozambique correspond to a region that is less populated and with low economic activity level. This is probably the reason why smaller floods may pass without much attention.

However, the flood of February 2000 attained such a level that it flooded the district towns of Nova Mambone and Machanga (Save basin) and Buzi (Buzi basin), causing deaths, forcing the evacuation of the population to refugee camps and totally disrupting the social and economic activities. According to DNA, the floods in these two river basins in the year 2000 were the biggest ones ever experienced.

2.7 FLOODS IN THE PUNGOÉ RIVER

Like the Buzi river basin, also the Pungoé river basin is shared between Mozambique and Zimbabwe. The major floods recorded in the Pungoé river were in the years 1962 and 1976. More recently, there were smaller floods in 1995 and 1996.

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[2] Although Massingir has discharged less than half of the peak flood inflow, reducing it from more than 16,000 m^3/s to less than 8,000 m^3/s.

The main impacts of these floods were the damages it caused to the EN6 road that links the city and port of Beira to Zimbabwe and the disruption to normal road traffic during days or even weeks.

2.8 FLOODS IN THE ZAMBEZI RIVER

Mozambique shares the Zambezi river with other seven SADC countries: Angola, Namibia, Botswana, Zambia, Zimbabwe, Tanzania and Malawi. The first five drain to the main river while Tanzania (through Lake Niassa) and Malawi have a share in the Chire basin. Mozambique is at the downstream end.

Cahora Bassa dam was built in 1975. Together with Kariba dam, the total reservoir storage is a huge reserve for regulation and flood control but the main purpose of both dams is hydropower production.

The biggest flood that occurred in the Zambezi basin since the Independence was in March 1978. Both Kariba and Cahora Bassa reservoirs were almost at full capacity when intense and prolonged rainfall in large areas of the basin originated the biggest ever flood into Kariba.

Due to the state of war at that time between Mozambique and the former Rhodesia, there were no direct communications between Kariba and Cahora Bassa. The information would be sent from Kariba to the headquarters of “Hidroeléctrica de Cahora Bassa” in Portugal that then would send it to Maputo to be conveyed to Tete and finally to the operators of Cahora Bassa, with a total delay of one to two weeks.

Therefore, when Kariba successively opened the spillway gates, Cahora Bassa did not have a complete knowledge about that, so it reacted late when the flood discharges of Kariba arrived. The reaction was to open almost immediately all the 4 spillway gates of Cahora Bassa that were still closed, thus creating an enormous flood wave that, adding to the floodwaters of the tributaries located downstream of the dam, completely flooded the Lower Zambezi.

The main impacts were that:

- a few people died
- one pier of the suspension bridge over the Zambezi river at Tete was damaged, which put serious limitations to the traffic until it was repaired, some years later
- most cultures in the agricultural areas on the flood plain were lost
- some secondary roads were badly damaged

Fortunately, the levees that protected the sugar cane plantations of the Sena Sugar company in Marromeu and Luabo were sufficient to sustain the flood, although last minute strengthening was required and, for a few hours, it appeared that they were on the brink of collapse.

The other big flood that occurred was in 1997. This was, however, much smaller than the 1978 flood and its impacts were felt only locally, particularly in the region of Caia, where extensive flooding of the flood plain occurred and the road embankment to the access to the ferry crossing the Zambezi river was destroyed in some extension. In this flood, Cahora Bassa plaid an important role, reducing an incoming flood of 12,000 m^3/s to a discharge of 2,000 m^3/s until the downstream tributaries had decreased their flow.

3 COPING WITH THE FLOODS

3.1 STRUCTURAL AND NON-STRUCTURAL MEASURES

With this history of floods and natural conditions for periodic occurrence of these extreme hydrologic events in one part or another of the country, one can ask how Mozambique tried to cope with the floods.

In general, when considering measures to minimise the negative impacts of the floods, those measures can be divided in two groups: structural measures and non-structural measures.

The group of structural measures includes usually: storage dams, dykes, flooding areas, river training. The group of non-structural measures includes measures such as: flood zoning, flood plain management, flood warning systems, emergency and evacuation plans, education and awareness raising, insurance.

Looking at past floods, it can be analysed how the Mozambican authorities have used these various types of measures for the attenuation of floods and what should be done in the future.

3.2 USE OF STRUCTURAL MEASURES

3.2.1 Storage dams

Large storage dams can contribute for the attenuation of floods if part of its storage capacity is reserved for floodwaters during the wet season.

In Mozambique, there are only five dams with sufficient storage capacity to have an impact on large floods, the already referred Pequenos Libombos, Corumana, Massingir, Chicamba and Cahora Bassa. It must be noted that Corumana, Massingir and Chicamba are built on tributaries and not on the main rivers. All these reservoirs incorporate in their operating rules a flood reserve during the rainy season.

At present, both Corumana and Massingir dams have a large flood storage capacity because the spillway gates have not been installed yet. Besides, due to serious leakage problems, Massingir is kept at a low storage level.

However, the reduction in the peak flood may not be great for large floods when the reservoirs are in normal conditions and when water demand during the dry season is high. Just for illustration purposes, consider some figures of the floods in 2000:

- the volume of flood inflow to Corumana dam in a period of 10 days was in the order of 1,100 x 10^6 m^3, almost **twice** the present storage capacity of the reservoir
- the total inflow to Massingir reservoir between January and March was about 9,500 x 10^6 m^3, approximately **eight** times the present storage capacity of the reservoir

It is also clear that, if Corumana was already completed with the installation of the spillway gates and Massingir was already rehabilitated, their contribution for the attenuation of the peak floods during February 2000 would have been even smaller as probably the water levels would have been closer to the FSL. Also the role of Cahora Bassa in flood control will be much smaller if a new power station is installed, increasing the capacity from the present 2,075 MW to about 3,600 MW.

In the short-term future, because the water demand in the Incomati and Limpopo basin is still low, particularly in terms of irrigation, the Corumana and Massingir dams can continue to have a significant role in the attenuation of floods. However, it should be remembered that they are on tributaries and not on the main rivers, Incomati and Limpopo. Cahora Bassa can obviously also continue to play an important role. The operating rules of all the existing large dams should be reviewed to check whether they work for flood attenuation as much as allowed by the other present uses of the dams.

In what new dams are concerned, it is obvious that they will have to be justified essentially by other uses (urban water supply, irrigation, industrial consumption), with flood control included in a multi-purpose perspective. This should be taken in due consideration in the feasibility and design stages of the new dams under consideration – Moamba on the Incomati river[3], Mapai on the Limpopo, Bué Maria on the Pungoé, Mepanda Uncua on the Zambezi[4].

As the floods originate mostly at the upstream countries, Mozambique could discuss with those countries how the operating rules of their large dams in the basins shared with Mozambique could incorporate the requirement of flood attenuation. For example, Pongolapoort dam, on the Maputo river, seems to be in conditions to give a significant contribution. Other large dams should be examined in each of the shared river basins.

There is, however, another aspect in which storage dams, both in Mozambique and in the upstream countries can contribute for the minimisation of floods: the increase in lead time for the flood warning systems.

On the other hand, the way most storage dams operate sometimes create a perverse effect. While they have a limited impact with the large floods, those dams absorb almost completely the small floods. This has not only negative environmental impacts but also eliminates the “routine” of the floods from the people’s minds and memory, so they are socially and psychologically less prepared for the large floods.

These last two aspects deserve attention in the definition and review of the operating rules of existing dams.

3.2.2 Levees

Levees for protection against floods have been used in Mozambique for irrigation areas (Chokwé, Marromeu, Luabo, Xinavane, Manhiça) and for the city of Xai Xai. This is a good solution that worked well in the past and may continue to do so in the future as long as it remains a local solution. When towns like Nova Mambone, Machanga and Buzi are clearly located at low levels in flood plains, levees could have been considered for their protection.

Levees should not create a section of the river that becomes too narrow during floods. This is the case of the protection dykes of MARAGRA near the town of Manhiça where the Incomati river is forced into a narrow cross-section and tends frequently to breach the dykes.

Levees have been designed for floods of return periods between 5 and 20 years. This seems a good design criterion as, for larger floods, there must be sufficient storage in the flood plain. However, when urban areas like Xai Xai and Chokwé are endangered, the levees protecting these areas should be raised to stand for floods of higher return periods.

Maintenance of the levees is essential. It is quite usual that some stretches of the levees will be at a lower level than what was initially designed and constructed, due to traffic of vehicles, people and animals, consolidation and so on. The responsibility for the maintenance must be clearly defined. A levelling of the levee’s crest should be done before the beginning of the rainy season to correct any low spot.

[3] A feasibility study for the Moamba dam is going to start in the coming months
[4] A feasibility study is already being executed

3.2.3 Flooding areas and river training

None of the flood prone basins have defined flooding areas to where part of the floodwater could be channelled and temporarily stored. There are in each basin areas which are normally flooded and that, until now, are not occupied for any particular use. Those areas should be evaluated and, if found to be of no great agricultural value, should be defined as flooding areas, with its use limited to activities of low economic value.

Mozambique has no experience of river training and the possible impacts in terms of flood attenuation. During the flood of February 2000, the Limpopo river just “ignored” one meander and continued in a straight path, cutting through a levee and through the downtown part of the city of Xai Xai.

Another particular situation deserving a detailed study is the mouth of the Limpopo river where past studies indicate that the flow becomes constricted and could eventually be improved by specific works.

3.3 USE OF NON-STRUCTURAL MEASURES

3.3.1 Flood zoning

Flood zoning is a fundamental step for Mozambique to better cope with the floods. It defines the risks associated to different zones along the river. In this way, the authorities responsible for territorial planning will have an indispensable information and the risks incurred by the already existing activities installed in the flood plain will be more objectively defined. This in turn will allow for better preparation of the emergency and evacuation plans.

For the various river basins of Mozambique that have experienced floods in the last 25 years, only the Umbeluzi basin was studied in terms of flood zoning, although after the maps were drawn and the risk zones were defined the subsequent analysis and decisions have not been made.

Consequently, this is one of the activities that Mozambique should give high priority[5]. One problem with the execution of the flood zoning studies will be the lack of maps at a sufficient scale, implying that a big effort will be required to produce them.

The idea of “return period” has permeated from the technical literature to the non-technical one, including daily newspapers. This has led to the use of concept beyond its definition and limits as a statistical concept. One problem of using the return period to define risks in flood zoning studies has to do with the operation of large reservoirs which transforms the natural series of flows into an artificial one.

3.3.2 Flood plain management

Urban or rural settlements, agriculture, tourism or industrial activities located in a flood plain are always subject to a measure of risk. Therefore, starting or expanding human settlements or economic activities in the flood plain should be subject to licensing and should require careful study and analysis. This obviously is more easily said then done but should remain as a guiding principle.

In this respect, it is also important to define who in Mozambique makes the decisions – is it DNA, DNOPT (National Directorate for Territorial Planning), the District Administrators, the Provincial

[5] A first study on flood risk analysis for the Maputo, Umbeluzi, Incomati, Limpopo and Save basins is going to be executed under DNA in the beginning of 2001.

Governors, the Minister for the area that controls the specific activity proposed to be developed in the flood plain? The question is not so much about which institution makes the decision but that the decision is made with full knowledge of all its implications, using the studies and analysis prepared by various other institutions, including the flood zoning studies.

The flood plain should also be considered and managed as a unit, although in Mozambique some of the main rivers form the limits between Provinces and Districts.

One type of occupation that has a significant impact in times of floods is the crossing of a flood plain by a road. Usually, the road is designed to minimise the hydraulic works - bridges and culverts, as they are much more expensive than the equivalent length of embankment. It is not surprising that for large floods, there are problems with road cuts and damages to bridges and culverts, as presented in point 2 of this paper.

The bridges and culverts are designed to be able to convey discharges corresponding to certain return periods: 50 – 100 years for bridges, 10 – 20 years for culverts. However, the design is usually made considering only the local conditions: velocity at the bridge, scour, freeboard. It is rare that the analysis of backwater effects is included in the design. Besides, the embankment plus bridges and culverts are designed for a flood of a certain return period but the design does not include an analysis of what could happen if a larger flood occurs. For example, the possibility of having certain lengths of the embankment built in such a way that they could be safely overtopped would introduce an additional measure of safety for the whole structure and allow for an easier recovery after the flood.

3.3.3 Flood warning systems

Flood warning systems are essential instruments to minimise the damages caused by floods, providing a forecast with days or hours in advance of the areas that are going to be flooded, water levels and eventually water velocity.

This forecast allows for a series of measures and interventions, from reservoir operation to strengthening of dykes, removal of equipment and evacuation of population. The forecast is derived from adequate mathematical models, using rainfall, water levels and discharges in upstream sections as inputs.

DNA has flood warning systems for the Umbeluzi, Incomati and Limpopo basins but, for the last two basins, the systems are considered inadequate and were quite ineffective during the recent floods.

Since the flood of 1978, a flood warning system has been proposed for the Zambezi river but nothing has been installed until now.

DNA is launching studies of flood warning systems and installation of telemetry equipment for the Incomati and Limpopo basins. These studies should gradually be extended to all the other flood prone river basins.

Various problems are associated with the installation and operation of flood warning systems in Mozambique:

- **shared river basins** – Mozambique needs a strong co-operation and support from the other SADC countries with which it shares various river basins. This includes a free and smooth flow of meteorological, hydrometric and reservoir data, collaboration between the responsible meteorological institutions for forecast of extreme meteorological events, consideration of attenuation of floods in Mozambique in the operating rules, support for the studies of flood warning systems and installation of telemetry equipment

- **strengthening of the rainfall and hydrometric networks** – the networks were already insufficient before the recent floods. There is a need for rehabilitation and expansion, as no flood warning system can work without receiving these data. The continuation and expansion of the HYCOS programs is needed.
- **robustness and redundancy of recording equipment** – past floods have shown that sometimes hydrometric stations are damaged and stop operating during a flood, when they are most needed. Therefore, robust installations and a certain redundancy are required.
- **communication systems** – one vital aspect is communications during the flood. Again, the experience of past floods has been that the communications system fails when it is most needed, both inside Mozambique and with the neighbouring countries. Particular attention for this aspect is then needed to ensure reliable communications during the flood period. The Internet introduced a valuable new and reliable channel.

3.3.4 Other non-structural measures

The issue of flood warnings by DNA and the ARAs is a first phase of a process that must be continued by the actions of other institutions like reinforcement of dykes and bridge foundations, alert notices to the population, preparation of temporary shelters, mobilisation of resources for an eventual evacuation and so on.

This is part of the **emergency and evacuation plans**, presently co-ordinated by the INGC (National Institute for Disaster Management).

A question of great importance in relation to the floods of the year 2000 is to analyse and understand why so many people in the flood plains became trapped and had to be rescued in very difficult circumstances. There are indications that in certain cases the traditional authorities did not believe in the flood warnings as it went against their experiences; in other cases, it was said that the warnings were too technical to be understood by people in rural areas.

However, there is no doubt that, at a certain point there were no safe escape routes for higher grounds and that there was not enough help for people to move. The safety of cattle was a major problem as also the concern of many people that their houses and property would be robbed when left behind.

Another important related issue is to raise the **awareness** of people in relation to floods and to promote **education programs**, at all levels, so that the population in general becomes more prepared to face large floods and to react adequately when they occur.

Insurance is sometimes suggested as a measure to minimise the consequences of floods. This was never done in Mozambique nor it appears to be feasible to be implemented in the near future.

3.4 RECORDS OF PAST FLOODS

The analysis of past floods that have occurred in Mozambique, even considering only those that happened in the last 25 years, is difficult because the corresponding data is not systematically collected, compiled, analysed and reported. Some floods are well documented and reported like the flood of 1978 on the Zambezi river or the flood of 1984 on the Umbeluzi river while most of the others that have been referred have disperse data and documentation. It is certainly a worthy effort to prepare a specific report for each significant flood that has occurred in each of the country's river basins.

In what concerns the floods of this year, it is worrying that, in spite of the specific recommendations made in the Technical Seminar[6], the record of maximum flood levels in each river basin and the preparation of maps of the flooded areas are still to be done. No serious analysis of the extreme floods of this year can be made without these maps and flood marks.

It would be equally important if satellite imagery, photo and videos made during the floods were collected and prepared for analysis and archives.

4 DIFFICULTIES IN IMPLEMENTING SOLUTIONS

Making the diagnosis is easier than finding solutions and this, in turn, is easier than implementing them. Mozambique has a long way to go to improve significantly its preparedness to manage the floods that will continue to occur in the future.

The country has significant constraints in terms of financial and qualified human resources. Mozambique has been receiving financial support from the international community and has qualified for the HIPC Initiative. The reduction in the debt service will contribute for the allocation of more funds for other areas.

Support for the country has also been given for the Water Sector, where the National Water Development Program deserves special mention as well as the long term support provided by the Government of the Netherlands. However, much more is needed, in particular for the field of water resources management.

DNA and the ARAs also need more qualified staff in the various disciplines dealing with water resources management, mainly water resources engineers, hydrologists, civil engineers, economists, lawyers, environmentalists and many others.

For this purpose, DNA could lead the Water Sector to establish a strong long-term co-operation program with the local universities, particularly with the Eduardo Mondlane University (EMU), including the components of basic training, specialised courses and applied research. EMU could then function as the Mozambican university link to tap the scientific and technical resources in the region, for which a project such as WaterNet can give an important contribution.

Many research themes can be found around the problems of floods and flood management. Some of them are:

- adaptation of the "return period" concept to floods in areas significantly influenced by large reservoirs upstream
- methodologies for statistical analysis of floods that are caused by diverse meteorological factors – cyclones, tropical depressions, cold fronts
- environmental impacts of floods, both positive and negative – one of the major difficulties is the lack of baseline studies
- reservoir operation for floods – with long-term forecasts, flood warnings. Operation for small floods.
- development of less complex rainfall-runoff models plus reservoir operation models to provide sufficient forecast capacity, even if not very accurate.

[6] Technical Seminar on the Floods in Mozambique in the year 2000, organised by DNA, Maputo, 30-31 May 2000

5 CONCLUSIONS

Mozambique will continue to be faced with large floods in the future. Floods cannot be avoided but more and continuous efforts have to be made to mitigate their adverse impacts. This will require the definition of a strategy that includes a judicious combination of structural and non-structural measures, based on a careful analysis of the past floods.

Strong support and co-operation from the neighbouring SADC countries is needed as well as financial and technical support from the international community.

Skilled human resources are essential, asking for adequate investments in education, training and research, where collaboration between universities and similar institutions from the region is a way to make the best use of scarce resources.